EXPERIMENTAL STUDY ON THE PROPERTIES OF CEMENT MORTAR WITH VARIOUS ADMIXTURES

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Abstract: **In this paper, mechanical and durability properties of cement mortar used for plastering over reinforced cement concrete exposed surfaces like sunshade, slabs, beams etc., near marine environment were studied by partial replacement of river sand which was used as fine aggregate by incorporating purified sea sand(S) as filler at various percentage of 5, 10, 15, 20 and 25 and carbonated coconut shell ash(CA) as a pozzolanic material at 0.5%, 1%, 1.5%, 2%, and 2.5%. Finally the mortar properties were improved using Azadirachta Indica extract (U) at the percentage of 0.5,1,1.5 and 2 in order to improve the durability, so as to minimize the corrosive effect of steel in RCC. The mechanical properties were investigated by compression test and flexural strength test and the durability characteristics were evaluated by the resistivity test of mortar. The results revealed that, the mechanical properties were decreased and the durability property was significantly improved while substituting sea sand and hence sea sand of 15% was considered for further quality enhancement. For further improvement by substituting CA of 1.5% revealed better results and Azadirachta Indica Extract of 0.5, 1.0, 1.5 and 2% gradually improved the mechanical property and 1% of extract considerably improved the durability property of CM. Significant improvement in the durability test results revealed that, there was high reduction in permeability and hence the corrosion of steel in RCC can also be reduced while coating with mortar.**

Keywords: **Sea Sand, Carbonated Coconut Shell Ash, Azadirachta Indica.**

I. INTRODUCTION

The chemical deterioration of concrete in marine environment has been a topic of interest to concrete technologies in the last few decades. The presence of sulphate and chloride ions in marine environment causes deterioration [1]. Besides the strength/weight ratio, the other factor that is of significant for structure is the long term durability, which is affected to a large extent by the permeability. Concrete with high permeability will provide ready access for both water and harmful substances resulting in deterioration of either concrete or steel reinforcement embedded in the concrete or a combination of both [2]. In concrete, the porosity, which is corrected by the pore structure, is essential, which act as passage for this chlorides [3].

India, which has lengthy sea shore and hence possess marine environment. The reinforced steel in concrete used in buildings has been deteriorated against corrosion because of chemicals, even though the exposed concrete surfaces such as roof slab, sunshade, beams etc., which are plastered with CM. The exposed RCC surfaces, which are plastered with CM is only the main threshold for chemical substances which cause deterioration to concrete through the pores of plastered materials as well as cover of concrete. If through proper care in using materials for plastering of required thickness, as well as with required cover in concrete, which will reduce the pores and the entry of harmful substances can be prevented, i.e., treatments that penetrate or are applied on the surface of the reinforced concrete member to prevent the entry of chloride ion in to the concrete [4].

It was verified that, the use of dredged marine sand in substitution of raw sand maintained or reduced the accessible pores, the sorptivity and the water penetration depth under pressure [5], this lead to increase in service life, which is the measure of its durability, ie., the resistance of sea sand mix to chloride ion penetration is greater than that of river sand mix[2].The sea sand containing concrete and the desalted sea sand containing concrete are more resistant to chloride ion penetration compared to the concrete made with river sand, as which has relatively lower clay content compared to river sand and consequently, the permeability of the concrete is affected [6].

In tropical regions, concrete exposed to elevated temperature accelerate hydration and non-uniform distribution of hydration products [7, 8]. This generate a great porosity and an increase of the compressive strength at early age and a decrease at late age [9], but Carbonation leads to a significant reduction in the permeability and porosity of concrete[10]. The presence of some mineral admixtures such as natural pozzolan flyash or granulated blast furnace slag in the cement can modify the kinetic of hydration, reduce porosity, heat evolution and minimize the disorders caused by the temperature rise according to the characteristics of these admixtures and their replacement rates, in hot climates [11].

In this text, the mortar practically adopted to cover the exposed RCC surfaces as plaster, in order to prevent the penetration through the RCC surfaces was tested by partly replacement of fine aggregate(FA) of river sand with materials like purified sea sand as filler and CA as pozzolanic material with Azadirachta Indica Extract as a binding admixture.

II. EXPERIMENTATION

A. Materials used

Ordinary Portland cement (OPC) with fineness of 350m^2/kg having chemical composition as per table 1 was used. The sand used for the CM was locally available river sand with a specific gravity (SG) of 2.58 and fineness modulus (FM) of 2.819 with 1.18mm maximum size. The FM was obtained using sieve test as per ASTM C136 - 92 and for finding the SG, ASTM C 128 - 93 was followed and the results are tabulated in table 2.

Table I: Chemical Properties of OPC

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3
21.0-22.5	4.5-6.0	2.5-3.5	36.5-66.0	0.9-3.0	0-2.0

The seasand was collected from Indian Rare Earths Ltd, Kanyakumari Dist., South India, which is a Govt. of India organization, which dredges offshore marine sand and separate minerals from this raw sand and this minerals are used for various purpose. The various minerals separated are Ilmonite, rutile,zircon,garnet, monazite, sillimanite, Kyanite, Leucoxene, quartz and shells. After mineral extraction, the residual raw sand is kept as waste material which having specific gravity of 2.59 and FM of 1.987, which was used as filler material by partial replacement of river sand for all the tests.

TABLE II: FINENESS MODULUS AND SPECIFIC GRAVITY OF RIVER SAND BY VARIOUS % REPLACEMENT OF SEA SAND

	5%	10%	15%	20%	25%
FM	2.336	2.28	2.231	2.19	2.152
SG	2.55	2.544	2.53	2.527	2.51

The CA was obtained by burning coconut shell under controlled combustion process (carbonation). The burning temperature was within the range of 600^{o}C to 850^{o}C. The ash obtained was ground in a ball mill for 30 minutes and sieved using 300 micron sieve, its appearance colour was grey. XRD analysis confirmed, SiO_2 more in percentage with Al_2O_3, MgO and Fe_2O_3 as other major constituents which are hardest substances. Some other oxides viz., CaO, K_2O, Na_2O and MnO were also found in traces [14].It has been established that amorphous silica was found in some pozzolanic materials reaction with lime more readily than those of crystalline form. ASTM C 618 – 78 specifies that any pozzolana that will be used as cement binder in concrete requires a minimum of 70% of silica, alumina and ferric oxide. As per elemental test using X-ray spectrometer test(XRF), CA has SiO_2, Al_2O_3 and Fe_2O_3 as 12.4% , 45.05% and 15.6% respectively[14,15] which is in line with the ASTM, as total percentage of these materials is more than 70%, thus CA fulfills the requirement for a pozzolana[16].

Fig. 1. Carbonated Coconut Shell Ash

Azadirachta Indica (commonly known as Neem) is composed of numerous naturally occurring organic compounds. Most of these compounds have significant number of oxygen, sulphur and nitrogen atoms incorporated in the structure. The adsorption of such compounds on the metal surface creates a barrier leading to a decrease in the interaction between the metal and the corrosive environment. Azadirachtin is present at highest concentration in the mature seeds which is responsible for the inhibitive effects of the plant extract. [17].

Fig. 2. Azadirachta Indica Seeds

For preparation of the extract, Azadirachta Indica seed was dried in open air under cool and dry atmosphere and cracked to separate their outside brown layer coat. Only brown red seed was collected and ground in to powder and sieved through 600µ sieve. 50g powder was taken in a RB flask and 200ml doubly distilled water was added and heated at 500^{o}C temperature for 1 hour and allowed to cool for 1 hour at room temperature. The cooled solution was then filtered with ordinary filter paper twice and finally filtered with watman filter paper no.1 and stored in a air tight container under room temperature till the use. The water used for preparing mortar was ordinary potable water of locally available.

Fig. 3. Preparation of the Extract

B. *Mixtures Used*

Prior to testing, mortar samples were prepared with a cement sand ratio of 1:3 and w/c ratio of 0.4. The sand was formulated by varying the replacement with sea sand of 0% to 25% having FM and SG as per the table-2 and also with CA of 0% to 2.5%. Inhibitor extract was added at a rate of 0.5%, 1.0%, 1.5% & 2.0% by weight of cement.

C. *Specimen preparation, curing and testing*

The specimens were cast using cast iron moulds of standard dimension. After 24 hours the specimens were removed from the moulds and placed in clean water for curing. The specimens were removed from the curing tank after 7 and 28 days and subjected to compressive, flexure and resistivity tests. For each mix, 3 specimens were cast corresponding to each age.

Compressive strength test was conducted using 50mm mortar cubes and the test was conducted at the ages of 7 and 28 days. The compressive strength of the specimen was calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area. A two point flexure test was conducted at the ages of 7 and 28 days as per BSEN 12390-5:2000. Flexural test was conducted on mortar specimen of size 100x100x500mm.

For the resistivity test, 50mm mortar cubes were used and the measurements were made at 7 and 28 days. The experimental setup consists of two copper plates attached to the upper and lower surfaces of the mortar sample and two wooden non-conductive blocks were placed under and on the sample. The electrical resistance values(R) were read from the electrical devices and the resistivity values were calculated using the following formula:

$$r = RA/L \qquad (1)$$

where, R is the resistance in Ω; A is the area of sample in m^2; L is the length of sample in m and 'r' is the resistivity in Ωm.

III. RESULTS AND DISCUSSION

A. *Material Properties*

As per sieve analysis, it was observed that, the FM slightly decreased from 2.8 to 2.7, as there was not too much variation in size, as the river sand taken was having a maximum size of 1.18mm. After replacement with sea sand, at various percentages of 0.5, 10, 15, 20 and 25, the FM obtained was 2.819, 2.796, 2.778, 2.768, 2.756 and 2.744 respectively. For each 5% replacement with the Sea sand, the decrease in percentage of FM for the fine aggregate was 0.50 and the SG was ranging from 2.88 to 2.5.

B. *Compressive Strength Test*

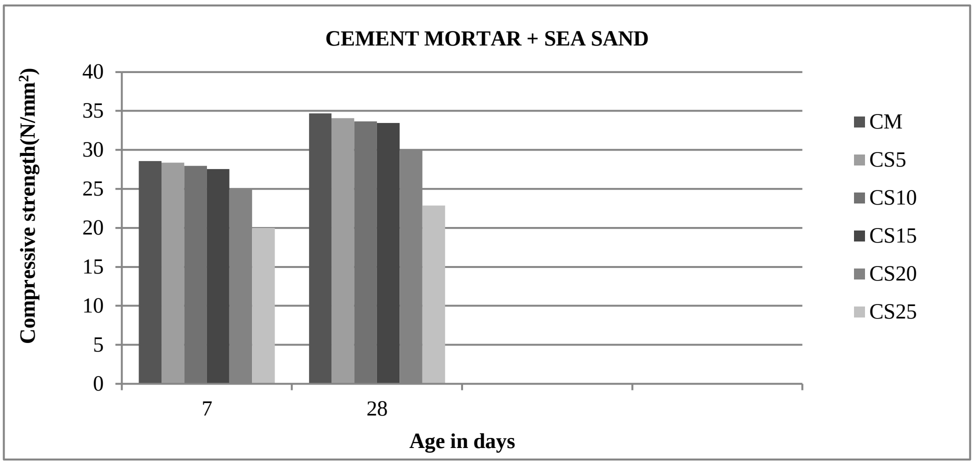
The compressive strength values for all the mixtures were tabulated in table 3 and plotted in fig 4. Initially the test was conducted with CM using OPC alone, which yielded compressive strength as 28.57Mpa and 34.69Mpa at the age of 7 and 28 days and further using Sea sand at various percentage by replacing of river sand, it was observed that, for all the ages, while increasing the replacement of river sand using Sea sand, the compressive strength was decreasing. At the age of 28 days, the decrease in strength in percentage was very low as 1.76, 2.94 and 3.52, by replacing with 5%,10% and 15% sea sand, but this value increased as 13.52 and 34.07 while replacement using 20% and 25% sea sand, when comparing with the CM. Sudden decline was observed after 15% sea sand at the age of 28 days and similarly for other ages also.

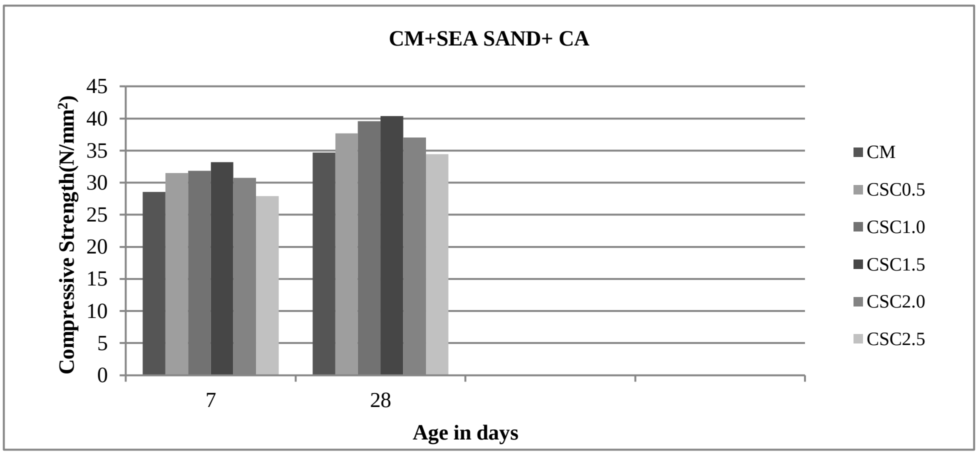
The compressive strength of the mix M4 was further improved by partial substitution of CA at various percentage of 0.5, 1.0, 1.5, 2.0 and, 2.5 by weight of river sand and the same quantity of river sand was replaced. At the age of 90 days, when comparing with the CM, at 0.5% replacement, there was a surge in increase from – 4.3% to +10.95% while adding with the mix M4 which is the indication of pozzolanic impact of CA added, ie., use of pozzolans can lead to increased compressive and flexural strengths [16].But further increase in percentage of CA was not producing too much increase in strength. At 1% and 1.5%, there was a slight increase in strength of 14.15% and 16.46% with a maximum increment percentage of 1.81% between 1% and 1.5% of CA. After 1.5% replacement, the strength was suddenly decreasing, which is similar to that, the compressive strength decreased with increasing percentage replacement of OPC with CA[16] and also more fineness of both Sea sand and CA. From the test results, the mix M9 were considered for further testing, as which has yielded the maximum strength.

Table III: Compressive Strength

Mix	Description	Compressive Strength (MPa)	
		7 days	28 days
M1	CM	28.57	34.69
M2	CM +S5	28.37	34.08
M3	CM +S10	27.96	33.67
M4	CM+S15	27.55	33.47
M5	CM+ S20	24.90	30.00
M6	CM+ S25	20.00	22.87
M7	CM+S15+ CA0.5	31.52	37.71
M8	CM+S15+ CA1.0	31.88	39.60
M9	CM + S15 + CA1.5	33.22	40.40
M10	CM+ S15+ CA2.0	30.76	37.04
M11	CM+ S15 + CA 2.5	27.94	34.45
M12	CM+S15+CA0.5+U0.5	34.31	41.23
M13	CM+S15+CA1.5+U1.0	37.21	43.07
M14	CM+S15+CA1.5+U1.5	37.75	42.75
M15	CM+S15+CA1.5+U2.0	38.98	42.05

For further tests, with the above mix, the Azadirachta Indica seed extract was used at 0.5%, 1%, 1.5% and 2% by replacement of water. At 0.5% replacement, the increase in strength percentage towards CM was 18.85 at 28days and this percentage was increased to 24.16 for 1% replacement. Beyond this percentage i.e., at 1.5 and 2% the strength was decreased at higher ages of 28 days. Hence the mix with 1% extract was considered to increase the compressive strength of the specimen at higher ages.





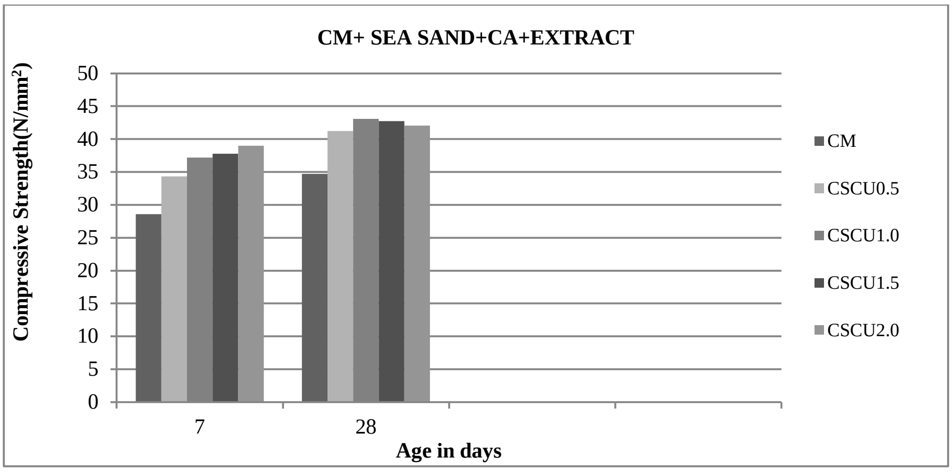


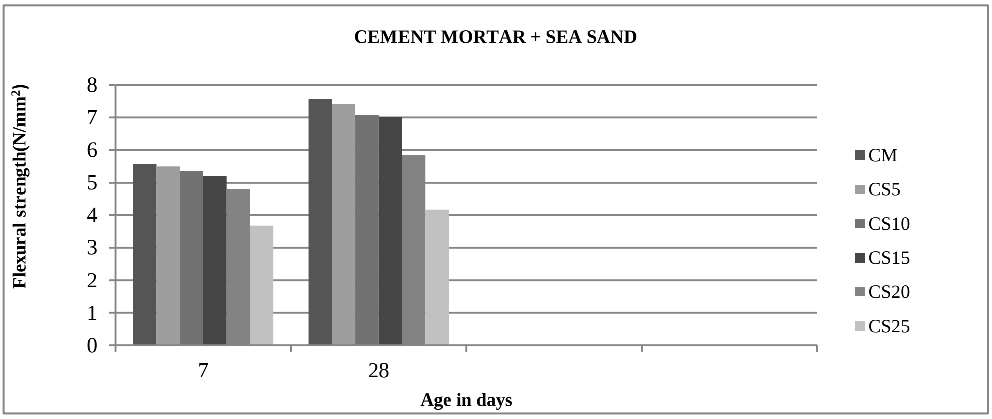
Fig 4. Variation of Compressive Strength

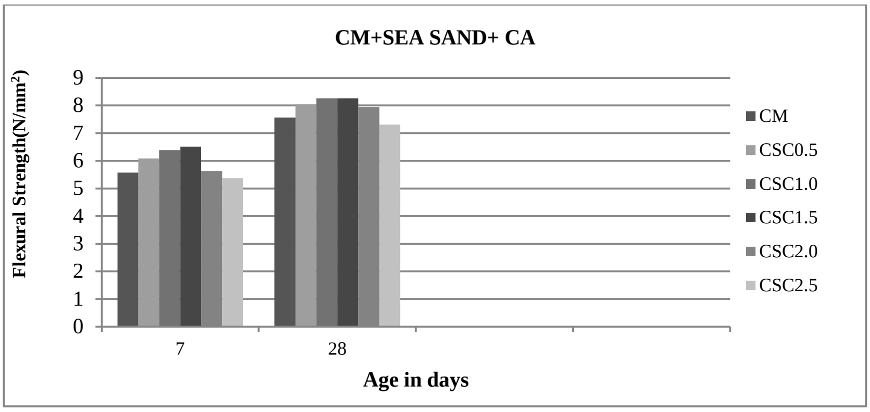
C. Flexural Strength Test

The same mix proportions used for compression test were also used for finding flexural strength. From table 4, the increase or decrease in percentage of flexural strength values compared to CM for most of the mixtures in all the ages are more or less same as compressive strength values. Replacing more percentage of sea sand envisaged decline in flexural strength, because of more fineness in sand.

Table IV: Fleural Strength

Mix	Description	Flexural Strength (MPa)	
		7 days	28 days
M1	CM	5.57	7.56
M2	CM +S5	5.50	7.42
M3	CM +S10	5.35	7.08
M4	CM+S15	5.20	7.01
M5	CM+ S20	4.80	5.84
M6	CM+ S25	3.68	4.17
M7	CM+S15+ CA0.5	6.08	8.05
M8	CM+S15+ CA1.0	6.38	8.26
M9	CM +S15 +CA1.5	6.51	8.26
M10	CM+ S15+ CA2.0	5.63	7.94
M11	CM+ S15+CA 2.5	5.36	7.31
M12	CM+S15+CA0.5+U0.5	6.55	8.52
M13	CM+S15+CA1.5+U1.0	6.92	8.78
M14	CM+S15+CA1.5+U1.5	7.25	8.97
M15	CM+S15+CA1.5+U2.0	7.62	9.32





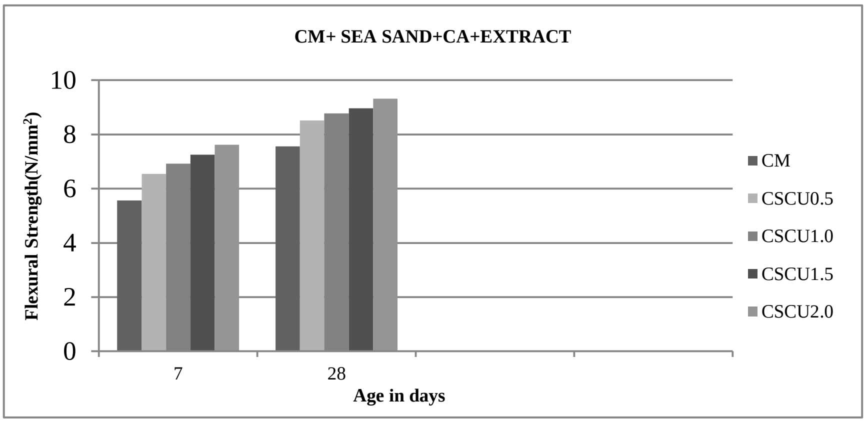


Fig. 5. Variation of Flexural Strength

While adding CA, the mix M9 exhibited more strength and further addition of CA led to decrease in strength. Adding more percentage of Azadirachta Indica extract has induced the flexural strength considerably. At 1.5% & 2% extract, the strength has decreased at higher age of 28 day. For 1% extract, the strength has increased to 16.13% more than the M1 mix. Hence the mix M13 is considered to be more suitable. It was noted that, the flexural strength variation was similar to compressive strength variation

D. Split Tensile Strength Test

From table V, it has been proved that by replacing more percentage of sea sand, decline in split tensile strength was observed. This is due to more fineness in sand.

Table V: Split Tensile Strength Values

Mix	Description	Split tensile Strength (MPa)	
		7 days	28 days
M1	CM	5.57	7.56
M2	CM +S5	5.50	7.42
M3	CM +S10	5.35	7.08
M4	CM+S15	5.20	7.01
M5	CM+ S20	4.80	5.84
M6	CM+ S25	3.68	4.17
M7	CM+S15+ CA0.5	6.08	8.05
M8	CM+S15+ CA1.0	6.38	8.26
M9	CM +S15 +CA1.5	6.51	8.26
M10	CM+ S15+ CA2.0	5.63	7.94
M11	CM+ S15+CA 2.5	5.36	7.31
M12	CM+S15+CA0.5+U0.5	6.55	8.52
M13	CM+S15+CA1.5+U1.0	6.92	8.78
M14	CM+S15+CA1.5+U1.5	7.25	7.97
M15	CM+S15+CA1.5+U2.0	7.62	7.32

While adding CA, the mix M9 exhibited more strength and further addition of CA led to decrease in strength. The increase in strength percentage was 9.26% compared to cement mortar specimen.

When Azadirachta Indica seed extract was added the strength was increased up to 1% replacement. At 1.5% & 2% extract, the strength has decreased at higher age of 28 days. For 1% extract, the strength has increased to 29% more than the M1 mix. Hence the mix M13 is considered to be more suitable. It was noted that, the Split tensile strength variation was similar to compressive strength variation.

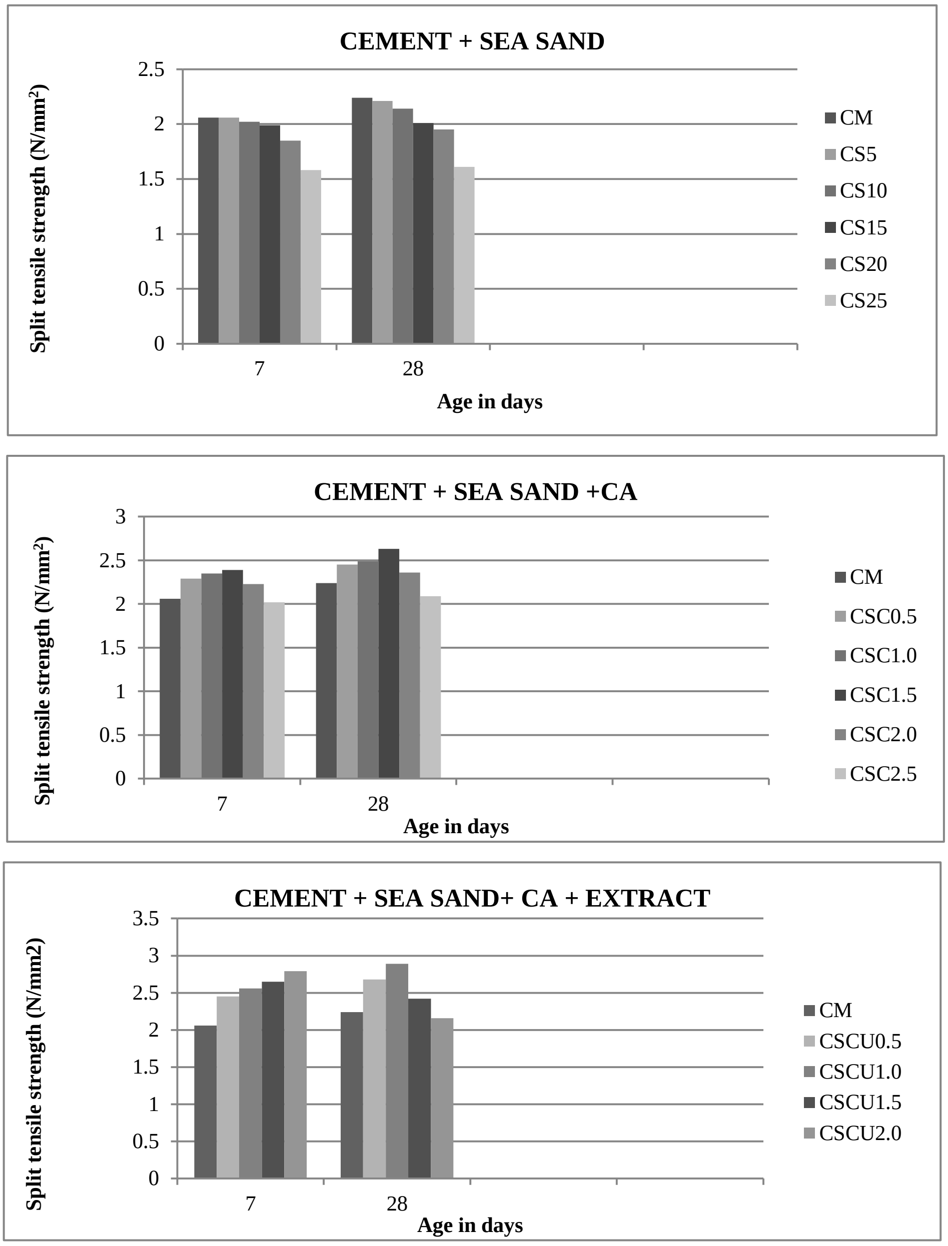


Fig 6. Variation of Split tensile Strength

E. Resistivity

From the table VI, the results at earlier ages showed that for the binder contents with different percentages of sea sand, coconut shell ash and azadirachta indica extract the probability of corrosion decreases as the electrical resistivity values are significantly more for the age of 28 days than other early ages. Considering the mix M1, at the age of 7 days, the resistivity is 69 Ωm and at the age of 28 days this value is gradually increased to 81 Ωm.

For the mix containing purified sea sand alone, increase in percentage of sea sand lead to a decrease in the electrical resistance values. It was observed that, the increase in percentage of sea sand, higher the probability of corrosion.

Considering the compressive strength, resistivity and economical alternative of river sand using sea sand, the mix M4 has been considered for effective improvement of durability properties by adding coconut shell ash of various percentages.

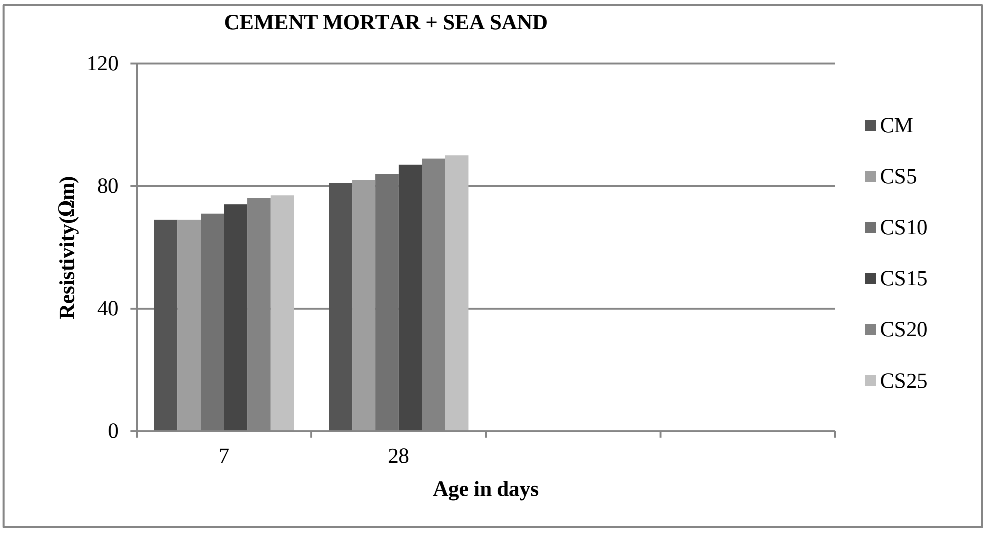
Table VI: Resistivity

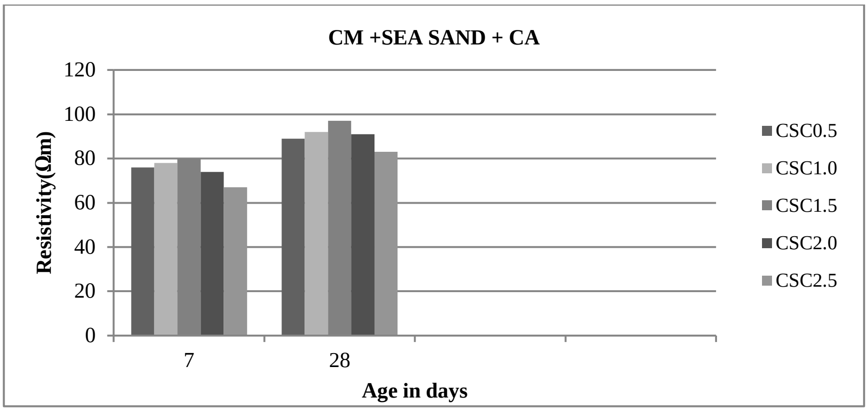
Mix	Description	Resistivity(Ω)	
		7 days	28 days
M1	CM	69	81
M2	CM +S5	69	82
M3	CM +S10	71	84
M4	CM+S15	74	87
M5	CM+ S20	76	89
M6	CM+ S25	77	90
M7	CM+S15+ CA0.5	76	89
M8	CM+S15+ CA1.0	78	92
M9	CM + S15 + CA1.5	80	97
M10	CM+ S15+ CA2.0	74	91
M11	CM+ S15 + CA 2.5	67	83
M12	CM+S15+CA0.5+U0.5	84	102
M13	CM+S15+CA1.5+U1.0	88	102
M14	CM+S15+CA1.5+U1.5	91	104
M15	CM+S15+CA1.5+U2.0	92	106

From the results it was observed that upto 1.5% partial substitution of CA, the resistivity values was decreased. At the higher age of 28 days, for 1.5% substitution of CA, the resistivity value has increased to 97 Ωm, while this value is 87 Ωm for the mix M4. At 2 and 25% replacement of CA, the resistivity values at the age of 28 days has decreased to 91 Ωm and 83 Ωm respectively and further increase in the percentage of CA may tend to decrease the resistivity and hence durability

This attributed to decrease in permeability at lower pozzolanic replacement which led to initial filling of voids, however at higher levels of pozzolan substitution, there was insufficient quantity of calcium hydroxide to react with the excess pozzolan, thus creating pores in the mx and hence reducing durability. Hence for further testing with partial substitution of extract, the mix M9 has been considered for influencing the durability properties.

The test results showed that the addition of extract lead to appreciable amount of increase in resistivity. At higher age of 28 days, higher resistivity values were observed at 1% replacement of extract. Beyond this percentage, the resistivity values were decreased.Fr 1% replacement of extract, at the age of 28 days the resistivity value is steeply increased to 105 Ωm. this value is 29.6% more than the resistivity value of cement mortar which is 81 Ωm.





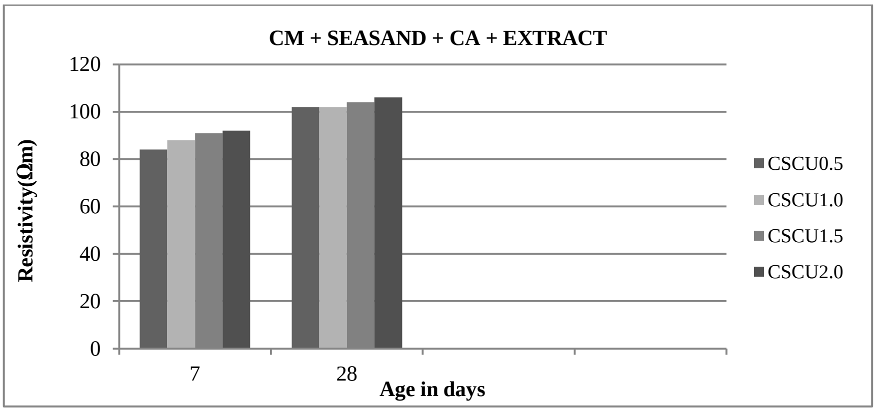


Fig. 7. Variation of Resistivity

V. CONCLUSION

As per this study, the results obtained can be summarized as follows. According to sieve analysis, all the mixtures having purified sea sand substitution has less FM than river sand alone. Replacement with Sea sand, CA and Azadirachta Indica seed extract produces required workability of mortar. Replacement with Sea sand decreases the compressive strength and flexural strength, but which can be overcome by replacing with CA up to 1.5% and more than 1.5% replacement decrease both compressive and flexural strength. Use of purified sea sand is recommended, because which is the waste material, also which highly decreases the water absorption percentage, because of more fineness. Similar result was obtained for split tensile test also. The resistivity results showed that, steep increase was scaled at higher ages for the mix containing 1% of extract with 1.5% of CA and 15% of Sea Sand. Beyond this percentage the resistivity values were decreased at the higher age of 28 days.

This study clearly shows that Sea Sand can be economically and successfully used up to 15% with 1.5% of CA and 1 % of Azadirachta Indica extract in order to improve the mechanical as well as the durability properties of cement mortar, which can be used as a protective coat over exposed RCC marine structures so that the corrosion effect can be significantly reduced.

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